

SECONDARY BATTERY AND MANUFACTURING SYSTEM AND METHOD THEREFOR

INCORPORATION BY REFERENCE

5 **[0001]** The disclosure of Japanese Patent Application No. 2003-35272 filed on February 13, 2003, including the specification, drawings and abstract is incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

10 1. Field of the Invention

[0002] The invention relates to a secondary battery and a manufacturing system and method therefor. More particularly, the invention relates to a secondary battery in which a plurality of cells are connected together in one direction, and a manufacturing
15 system and method therefor.

2. Description of the Related Art

[0003] As a secondary battery to be mounted in a hybrid vehicle, a cylindrical, sealed nickel hydrogen secondary battery having a construction such as that shown in FIG. 14, is known, for example (Electric Vehicle Handbook (2001), Electric Vehicle Handbook,
20 pp. 261-262, Maruzen).

[0004] Referring to FIG. 14, a secondary battery 1400 includes a case 1410, a positive electrode collector 1420, a positive electrode plate 1422, a negative electrode collector 1430, a negative electrode plate 1432, a separator 1440, an insulation gasket 1450, a cap 1460, a safety valve 1470, a sealing plate 1480, and an insulation ring 1490. In this
25 secondary battery 1400, the cap 1460 is the positive electrode and the case 1410 is the negative electrode.

[0005] In order to obtain high voltage using the secondary battery 1400 of this construction, it is necessary to connect a sufficient number of the secondary batteries together to obtain the desired voltage. In this case, however, connective resistance is
30 generated between the cap 1460 of the secondary battery 1400 and the case of the adjacent secondary battery, which reduces the overall voltage, thereby reducing the efficiency of the secondary battery.

[0006] To solve this problem, JP(A) 4-341766 discloses a wound multiple-cell, sealed secondary battery that improves the efficiency of the secondary battery by reducing

voltage loss between cells and inhibits the active material utilization rate from falling at the outer periphery of the battery. This secondary battery is provided with a bipolar electrode plate, a first cell electrode plate and an end electrode plate. The bipolar electrode plate includes positive and negative electrode active material to the left and right of a single
5 band-shaped collector. The bipolar electrode plate also has a protruding member that separates the cells at the center portion of the collector. The first cell electrode plate and the end cell electrode plate include a positive or negative electrode active material provided on either the left or the right of a predetermined portion of the single band-shaped collector. The first cell electrode plate and the end cell electrode plate also have a
10 protruding member that separates the cell from an adjacent cell at the upper portion or lower portion of the cell. These three types of electrode plates are layered upon one another such that the separator is sandwiched between the positive electrode plate and negative electrode plate, thus forming an electrode plate set. This electrode plate set is then wound in a spiral so as to form a plurality of integrated cells.

15 [0007] With the secondary battery disclosed in JP(A) 4-341766, voltage loss at the connecting portion between cells is able to be suppressed so voltage during discharge is able to be kept high. Accordingly, the efficiency of the secondary battery during discharge is able to be improved.

20 [0008] However, with the secondary battery according to the foregoing publication, when the wound set of electrodes is connected with a collector, the output voltage falls due to an increase in internal resistance. Moreover, a connection of this sort increases the number of parts, which in turn increases the number of man-hours it takes to manufacture the secondary battery.

25 [0009] Furthermore, with a secondary battery that outputs high voltage, the life of the secondary battery decreases unless sufficient cooling is provided.

SUMMARY OF THE INVENTION

30 [0010] In view of the foregoing problems, this invention thus provides a secondary battery and manufacturing system and method therefor, capable of improving output and battery life, reducing the number of parts used, and reducing the number of man-hours necessary for manufacturing the secondary battery.

[0011] A first aspect of the invention relates to a secondary battery. The secondary battery has i) a first cell comprising a flat sheet-shaped first electrode of one polarity and a flat sheet-shaped second electrode of another polarity layered on top of one

another with a separator disposed therebetween, and ii) a second cell aligned in the same direction as, and adjacent to, the first cell, the second cell comprising a flat sheet-shaped first electrode of one polarity and a flat sheet-shaped second electrode of another polarity layered on top of one another with a separator disposed therebetween. An edge portion of the first electrode in the first cell has a different polarity than an edge portion of the second electrode in the second cell, and is overlapped and joined with the edge portion of the second electrode in the second cell.

[0012] Each cell of the plurality of cells in the secondary battery includes the layered first and second electrodes. The edge portion of the first electrode of the first cell in the secondary battery overlaps with the edge portion of the second electrode of the adjacent second cell. Accordingly, one of the electrodes in one cell is directly connected to one of the electrodes in another cell so internal resistance from connecting the cells is able to be reduced. As a result, output from the secondary battery improves. Also, the parts to connect the cells, in addition to the processes for incorporating those parts, become unnecessary. As a result, it is possible to provide a secondary battery able to improve output and which reduces the number of parts and manufacturing processes.

[0013] A second aspect of the invention relates to a manufacturing system adapted to manufacture a secondary battery. The manufacturing system includes i) a forming apparatus that forms a first cell comprising a flat sheet-shaped first electrode of one polarity and a flat sheet-shaped second electrode of another polarity layered on top of one another with a separator disposed therebetween, and ii) a moving apparatus that moves the first cell with respect to the forming apparatus so that the forming apparatus can form a second cell comprising a flat sheet-shaped first electrode of one polarity and a flat sheet-shaped second electrode of another polarity layered on top of one another with a separator disposed therebetween, such that an edge portion of the second electrode in the second cell, which has a different polarity than an edge portion of the first electrode in the first cell, is overlapped with the edge portion of the first electrode in the first cell, and the secondary battery has a shape in which the first cell and the second cell are aligned in one direction.

[0014] The forming apparatus forms the first cell such that the edge portion of the first electrode is of one polarity and the edge portion of the second electrode is of another polarity, and the edge portion of the first electrode is offset from the edge portion of the second electrode, for example. Also, the forming apparatus forms the second cell which includes a flat sheet-shaped first electrode of one polarity and a flat sheet-shaped second electrode of another polarity layered on top of one another with a separator

disposed therebetween, such that an edge portion of the second electrode in the second cell, which has a different polarity than an edge portion of the first electrode in the first cell, overlaps with the edge portion of the first electrode in the first cell. Accordingly, the edge portion of the first electrode and the edge portion of the second electrode are connected at a connecting portion between the first and second cells, which obviates the need for a separate part to connect the plurality of cells. As a result, internal resistance generated by connecting the cells is reduced and output of the secondary battery is improved. Further, because the forming apparatus forms the second cell so that the second cell connects to the first cell, a separate process for connecting adjacent cells becomes unnecessary. Therefore, a manufacturing system for a secondary battery is able to be provided which increases output of the battery while enabling the number of parts and manufacturing processes to be reduced.

[0015] A third aspect of the invention relates to a manufacturing method for manufacturing a secondary battery that includes a plurality of cells aligned in one direction. This manufacturing method includes i) a first forming step for forming a first cell comprising a flat sheet-shaped first electrode of one polarity and a flat sheet-shaped second electrode of another polarity layered on top of one another with a separator disposed therebetween, and ii) a second forming step for forming a second cell comprising a flat sheet-shaped first electrode of one polarity and a flat sheet-shaped second electrode of another polarity layered on top of one another with a separator disposed therebetween, such that an edge portion of the second electrode in the second cell, which has a different polarity than an edge portion of the first electrode in the first cell, is overlapped with the edge portion of the first electrode in the first cell, and the secondary battery has a shape in which the first cell and the second cell are aligned in one direction.

[0016] In the first forming step, the first cell is formed such that the edge portion of the first electrode is of one polarity and the edge portion of the second electrode is of another polarity, and the edge portion of the first electrode is offset from the edge portion of the second electrode, for example. Also, in the second forming step, the second cell is formed which includes a flat sheet-shaped first electrode of one polarity and a flat sheet-shaped second electrode of another polarity layered on top of one another with a separator disposed therebetween, such that the edge portion of the second electrode in the second cell, which has a different polarity than the edge portion of the first electrode in the first cell, overlaps with the edge portion of the first electrode in the first cell. Accordingly, the edge portion of the first electrode and the edge portion of the second electrode are

connected at a connecting portion of the first and second cells, which obviates the need for a separate part to connect the plurality of cells. As a result, internal resistance generated by connecting the cells is reduced and a separate process for connecting adjacent cells becomes unnecessary. Therefore, a manufacturing method for a secondary battery is able to be provided which increases output of the battery while enabling the number of parts and manufacturing processes to be reduced.

[0017] A fourth aspect of the invention relates to a secondary battery. The battery has i) a first cell formed by layering a flat sheet-shaped positive electrode and a flat sheet-shaped negative electrode on top of one another with a separator disposed therebetween, and ii) a second cell which is aligned in the same direction as, and adjacent to, the first cell and is formed by layering a flat sheet-shaped positive electrode and a flat sheet-shaped negative electrode on top of one another with a separator disposed therebetween. An edge portion of the positive electrode in the first cell is overlapped and joined with an edge portion of the negative electrode in the second cell.

[0018] A fifth aspect of the invention relates to A secondary battery. The battery has i) a first cell formed by layering a flat sheet-shaped positive electrode and a flat sheet-shaped negative electrode on top of one another with a separator disposed therebetween, and ii) a second cell which is aligned in the same direction as, and adjacent to, the first cell and is formed by layering a flat sheet-shaped positive electrode and a flat sheet-shaped negative electrode on top of one another with a separator disposed therebetween. An edge portion of the first cell is overlapped and joined with an edge portion of the second cell. The edge portion of the first cell is different from the polarity of the edge portion of the second cell.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] The foregoing and further objects, features and advantages of the invention will become apparent from the following description of preferred embodiments with reference to the accompanying drawings, wherein like numerals are used to represent like elements and wherein:

FIG. 1 is a block diagram of a secondary battery according to a first exemplary embodiment of the invention;

FIG. 2 is a cross-sectional view of the secondary battery according to the first exemplary embodiment of the invention;

FIG. 3 is a block diagram of a manufacturing system for the secondary battery

according to the first exemplary embodiment of the invention;

FIG. 4 is a side view of a winding apparatus included in the manufacturing system shown in FIG. 3;

FIG. 5 is a top view of the winding apparatus included in the manufacturing
5 system shown in FIG. 4;

FIG. 6 is a side view of an insulation sheet winding apparatus included in the manufacturing system shown in FIG. 4;

FIGS 7A and 7B are flowchart illustrating a manufacturing method for the secondary battery according to the first exemplary embodiment of the invention;

10 FIG. 8 is a block diagram of a secondary battery according to a second exemplary embodiment of the invention;

FIG. 9 is a block diagram of a manufacturing system for the secondary battery according to the second exemplary embodiment of the invention;

15 FIGS. 10A and 10B are flowchart illustrating a manufacturing method for the secondary battery according to the second exemplary embodiment of the invention;

FIG. 11 is a block diagram of a secondary battery according to a third exemplary embodiment of the invention;

FIG. 12 is a block diagram of a manufacturing method for the secondary battery according to the third exemplary embodiment of the invention;

20 FIGS. 13A and 13B are flowchart illustrating a manufacturing method for the secondary battery according to the second exemplary embodiment of the invention; and

FIG. 14 is a block diagram of a typical secondary battery.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

25 [0020] In the following description and the accompanying drawings, the present invention will be described in more detail in terms of exemplary embodiments.

Exemplary embodiments of the invention will hereinafter be described with reference to the accompanying drawings. In the following description, like parts will be denoted by like reference numerals. Detailed descriptions of such parts that are repetitious will be
30 omitted.

[0021] [First Embodiment]

A first exemplary embodiment of the invention will now be described with reference to FIGS. 1 to 7B.

[0022] FIG. 1 shows a secondary battery 100 according to the first exemplary

embodiment of the invention. This secondary battery 100 has a plurality of cells aligned in one direction. The battery may, for example, be used to supply power to an electric motor (not shown) to be mounted in a hybrid vehicle, or as a power source for a household electrical appliance or the like.

5 **[0023]** As shown in FIG. 1, the secondary battery 100 includes a hollow shaft 110, a battery case 120, a positive electrode sheet 202, a negative electrode sheet 206, separator sheets 204 and 208, an insulation sheet (not shown), and an electrolytic solution (also not shown). The insulation sheet is wound on the inside of the battery case 120. As will be described later, the positive electrode sheet 202, the negative electrode sheet
10 206, and the separator sheets 204 and 208 are wound on the shaft 110 to the inside of the insulation sheet. The secondary battery 100 is then crimped at a predetermined crimping portion 130.

[0024] A coolant (not shown) is injected into the shaft 110 so as to cool the shaft 110 which inhibits, for example, degradation of performance (e.g., shortened life) due to
15 heat generation.

[0025] The cross-section construction of the secondary battery 100 according to the first exemplary embodiment of the invention will now be described with reference to FIG. 2. FIG. 2 is a cross-sectional view of the secondary battery 100 shown in FIG. 1 cut length-wise along the shaft 110.

20 **[0026]** Referring to FIG. 2, the secondary battery 100 includes a plurality of cells A and B. These cells A and B are arranged alternately. In each of the cells A and B, the positive electrode sheet 202, the separator sheet 204, the negative electrode sheet 206, and the separator 208 are wound.

[0027] The positive electrode sheet 202 and the negative electrode sheet 206
25 form edge portions of each cell (i.e., portions which protrude from the portion of the cell where the sheets are layered on top of one another) so that when two of the cells are connected, the positive electrode sheet 202 of one cell faces the negative electrode sheet 206 of the other cell. The width of the edge portions (i.e., the length in the axial direction) can be preset based on, for example, the number of windings of the layered
30 sheets (or the outer diameter of the secondary battery 100) or a method for connecting cells (crimping, welding, pressure by a ring member, or the like).

[0028] The positive electrode sheet 202 and the negative electrode sheet 206 are both made of electrical conductive material. In this exemplary embodiment, the positive electrode sheet 202 is coated with sintered nickel, for example, and the negative electrode

sheet 206 is coated with a hydrogen alloy in a paste form, for example, but the invention is not limited to this.

5 [0029] The separators 204 and 208 are sheets for separating the positive electrode sheet 202 from the negative electrode sheet 206. In this exemplary embodiment, these separators 204 and 208 are made of a non-woven fabric or a finely perforated film, for example, but the invention is not limited to this. Any material may be used as long as it is stable with respect to the electrolytic solution and has a saturation rate for the electrolytic solution that fulfills a predetermined condition.

10 [0030] Cell B is formed after cell A. At the connecting portion where cell B connects with cell A, the edge portion of the electrode in cell B is wound around so as to overlap the edge portion of the electrode in cell A. Accordingly, the edge portion of the electrode in cell A is pressed toward the shaft 110 by the edge portion of the electrode in the adjacent cell B. This ensures the connection between cell A and cell B.

15 [0031] The number of windings of each of the sheets is not particularly limited, but may be predetermined based on, for example, the capacity of the secondary battery 100. Also, the number of cells A and B are not limited to the number shown in FIG. 2. Rather, the number may be determined based on, for example, the voltage or the like required of the secondary battery 100.

20 [0032] This construction obviates the need for a collector which is necessary in a typical secondary battery. As a result, even if a plurality of cells are connected to obtain a predetermined voltage, the internal resistance from connecting the cells can be reduced. Accordingly, output from the secondary battery can be improved and the number of parts can be reduced.

25 [0033] A manufacturing system 1000 for manufacturing the secondary battery according to the first exemplary embodiment of the invention will now be described with reference to FIG. 3. This manufacturing system 1000 includes manufacturing equipment that carries out various manufacturing processes, from introducing the structural materials of the secondary battery (i.e., shaft, electrode sheets, separator sheets, insulation sheets, electrolytic solution, battery case, and the like) to sealing the battery case.

30 [0034] Referring to the drawing, the manufacturing system 1000 includes a system controller 300, a linear guide controller 302, a transfer apparatus 306, a shaft supply apparatus 312, an inserting machine 334, a battery case rack 332, a belt conveyer 340, two crimping machines 350, an electrolytic solution injecting machine 360 which is provided with a nozzle 362, two sealing machines 370, two winding apparatuses 400, and

an insulation sheet winding apparatus 600.

[0035] The system controller 300 is connected to each apparatus in the manufacturing system 1000, and controls the processes carried out by those apparatuses based on predetermined conditions.

5 [0036] The linear guide controller 302 controls the operation of the transfer apparatus 306 based on a command from the system controller 300.

[0037] Based on a command from the linear guide controller 302, the transfer apparatus 306 moves on a transfer rail 314 and rotates around to a predetermined location (illustrated by the dotted lines in FIG. 3) to supply the shaft 110, around which the sheets
10 have already been wound, to the inserting machine 334. The transfer apparatus 306 is provided with a loader 304, which in turn is provided with chucks 308. The loader 304 grabs the shaft 110 with the chucks 308 based on a command from the linear guide controller 302. When the transfer apparatus 306 rotates around to the predetermined location, the chucks 308 release the shaft 110 so as to supply it to a predetermined location.

15 [0038] The chucks 308 take the shaft 110 from the shaft supply apparatus 312 and holds it until supplying it to the inserting machine 334.

[0039] In this exemplary embodiment, the shaft 110 is a hollow shaft such as a tube, for example, but it may also be a solid shaft. When a hollow shaft is used, a coolant medium can be injected into the shaft. In this case, the coolant medium can be injected
20 into the shaft at the time the secondary battery is mounted (in a vehicle, for example), for example. Also, the shaft 110 may be a rigid metal body, for example, as long as it has a coating of insulation on the outside (the outside may be coated with resin, for example). This enables the inside of the shaft 110 to be insulated from the outside of the shaft 110.

[0040] The winding apparatus 400 winds the positive electrode sheet 202, the
25 negative electrode sheet 206, and the separators 204 and 208 on the shaft 110, as will be described later. In FIG. 3, the manufacturing system 1000 is provided with two of the winding apparatuses 400, but the invention is not limited to this. That is, more or fewer of the winding apparatuses 400 may be provided depending on, for example, the size of the secondary battery (i.e., the length in the axial direction) or conditions such as production
30 rate.

[0041] The shaft supply apparatus 312 supplies the shaft 110, which is part of the secondary battery, to the transfer apparatus 306 every predetermined cycle time according to a command from the system controller 300.

[0042] The inserting machine 334 inserts the shaft 110, onto which the positive

electrode sheet 202, the separators 204 and 208, the negative electrode sheet 206, and the insulation sheet 210 have been wound, into the battery case 120 according to a command from the system controller 300. The battery case 120 is supplied from the batter case rack 332 toward the wound shaft 110 according to a command from the system controller 300.

5 **[0043]** After the shaft 110 wound with the sheets has been inserted into the battery case 120, the crimping machine crimps the battery case 120 at predetermined locations so as to join the cells (FIG. 2). The predetermined locations are at portions at which one cell is connected to another (i.e., portions at which the edge portions (offset portions) of the electrodes of each cell overlap). This ensures connection between the
10 cells. Further, using the crimping method it is possible to reliably connect the overlapping edge portions of two adjacent cells in cases where two adjacent cells are unable to be connected by, for example, metallurgical bonding such as welding or pressing with a ring member or the like.

[0044] The electrolytic solution injecting machine 360 supplies electrolytic
15 solution to inside the battery case 120. This electrolytic solution may be, for example, diluted sulfuric acid or an aqueous potassium hydroxide, but it is not limited to this as long as the electrolytic solution has i) good ion solubility and ion conductivity, ii) no electron conductivity, and iii) a high stability temperature zone or a high break down voltage by which the solute in the electrolytic solution breaks down.

20 **[0045]** The sealing machine 370 seals the secondary battery after the electrolytic solution has been injected so as to prevent the electrolytic solution from leaking out. There are various methods for sealing including, but not limited to, pressing or inserting a sealing plate or a seal.

[0046] Assembly of the secondary battery is complete when the shaft 110 wound
25 with the sheets and the electrolytic solution are sealed in the battery case 120 and adjacent cells are joined through predetermined processes with the manufacturing equipment described above. The secondary battery is then transferred on the conveyer belt 340 to the next process (such as an inspection process).

[0047] The winding apparatus 400 used in the manufacturing system 1000
30 according to the exemplary embodiment of the invention will now be described with reference to FIG. 4, which is a side view of the winding apparatus 400.

[0048] As shown in the drawing, the winding apparatus 400 includes a pressure roller 402, a hydraulic piston 406, two sheet cutters 408, two sheet holders 412, an adhesive applying portion 416, two feed rollers 404, and four sheet rollers 410, 420, 430,

and 440.

[0049] The pressure roller 402 presses the sheets onto the shaft 110 with the pressure applied by the hydraulic piston 406. Once the winding of the sheets starts, the pressure roller 402 continues to press the sheets onto the shaft 110 with regulated hydraulic pressure.

[0050] The feed rollers feed the sheets from the sheet rollers to the sheet holders 412 while keeping the sheets in a predetermined state.

[0051] When a predetermined number of windings is complete, the sheet cutters 408 cut the sheets. When the sheets are not being wound, the sheet holders 412 hold the sheets in a predetermined state in preparation for the next winding process.

[0052] The positive electrode sheet 202 is originally wound on the sheet roller 410; the separator sheet 204 is originally wound on the sheet roller 420; the negative electrode sheet 206 is originally wound on the sheet roller 430; and the separator sheet 208 is originally wound on the sheet roller 440. A predetermined amount of tension is applied to these sheets so as to prevent them from sagging.

[0053] As shown in FIG. 2, the sheets rollers 410, 420, 430, and 440, are arranged so that the edge portion of the positive electrode sheet 202 and the edge portion of the negative electrode sheet 206 are offset. This arrangement is illustrated in detail in FIG. 5.

[0054] The sheets supplied from the sheet rollers are arranged in a predetermined location with the feed rollers 404 and supplied to the shaft 110 while passing between the sheet holders 412. The adhesive applying portion 416 applies an adhesive to the ends of the sheets to prevent the ends from coming away from the shaft 110. The end portions of the sheets are then feed to the shaft 110. The pressure roller 402 is pressed by the hydraulic piston 406 so as to press the sheets to the shaft 110. As a result, the ends of the sheets adhere to the shaft 110.

[0055] The fashion in which the winding apparatus 400 winds the sheets around the shaft 110 while the edge portions of the positive and negative electrode sheets are offset will now be described with reference to FIG. 5, which is a top view of the winding apparatus 400 with the sheets arranged in the predetermined location.

[0056] Referring to the drawing, the sheets wound around the shaft 110 are wound in the following order from the inside (nearest the shaft 110) to the outside (farthest away from the shaft 110) in the radial direction of the cell: the positive electrode sheet 202, the separator sheet 204, the negative electrode sheet 206, and the separator sheet 208.

The positive secondary battery 202 and the negative electrode sheet 206 are arranged so their edge portions are offset from one another. The cells A and B are thus formed by winding the sheets arranged in this way on the shaft 110, as shown in FIG. 2. Any one edge portion of each cell is formed of sheets all having one polarity, and the other edge
5 portion of each cell is formed of sheets all having another polarity, such that each cell A and B has both a positive pole (electrode) and a negative pole (electrode). This construction enables the edge portions to be used to connect adjacent cells together.

[0057] The insulation sheet winding apparatus 600 used in the manufacturing system 1000 will now be described with reference to FIG. 6, which is a side view of the
10 insulation sheet winding apparatus 600 shown in FIG. 3.

[0058] As shown in the drawing, the insulation sheet winding apparatus 600 includes a pressure roller 602, two feed rollers 604, a hydraulic piston 606, two sheet cutters 608, a sheet roller 610, and a sheet holder 612. The insulation sheet 210 is originally wound on the sheet roller 610 and a predetermined amount of tension is applied
15 to the insulation sheet 210 so that it does not sag.

[0059] The respective functions of the rollers, hydraulic piston 606, sheet cutters 608, sheet holders 612, and adhesive applying portion 616 are essentially the same as those of the rollers, the hydraulic piston 406, the sheet cutters 408, the sheet holder 412, and the adhesive applying portion 416 so they will not be repeated.

[0060] Once the shaft 110, around which the sheets have been wound by the winding apparatus 400, is supplied to a predetermined location, the insulation sheet winding apparatus 600 winds the insulation sheet 210 around the outer periphery of the shaft 110 so that the positive electrode sheet 202 or the negative electrode sheet 206 wound
20 by the winding apparatus 400 can be insulated from the outside.

[0061] The manufacturing method of the secondary battery 100 according to the exemplary embodiment of the invention will now be described with reference to the flowchart of FIGS. 7A and 7B. The manufacturing method may be used, for example, in the manufacturing system 1000 shown in FIG. 3.

[0062] In step S702, the system controller 300 initializes control data. This control data includes a counter p indicative of the number of windings of the sheets, the number of cells in the secondary battery, and the like.
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[0063] In step S704, the shaft supply apparatus 312 supplies the shaft 110 to a predetermined location according to a command from the system controller 300. This predetermined location is a location from which the chucks 308 are able to grab the shaft

110. This location can be changed depending particular characteristics of the shaft, such as the length of the shaft 110 and whether the shaft is hollow or solid.

5 [0064] In step S706, the loader 304 sets the shaft 110 in a predetermined initial state, in which both ends of the shaft 110 are grabbed by the chucks 308 provided on the loader 304.

[0065] In step S708, the system controller 300 moves (to the right in FIG. 3) the transfer apparatus 306 to a predetermined location for the winding apparatus 400 using the linear guide controller 302. This predetermined location is a location in which the winding apparatus 400 is able to wind the sheets onto the shaft 110.

10 [0066] In step S710, the winding apparatus 400 sets the positive electrode sheet 202, the negative electrode sheet 206, and the separator sheets 204 and 208 in an initial state. This initial state is a state in which the ends of the sheets are aligned and an adhesive is applied thereto.

15 [0067] In step S712, the winding apparatus 400 sets the sheets against the shaft 110. Accordingly, the ends of the positive electrode sheet 202, the negative electrode sheet 206, and the separator sheets 204 and 208 adhere to the shaft 110. Pressure is then applied to the ends by the pressure roller 402 so that they do not come away from the shaft 110.

20 [0068] In step S714, the winding apparatus 400 winds the positive electrode sheet 202, the negative electrode sheet 206, and the separator sheets 204 and 208 onto the shaft 110 while rotating the shaft 110 at a predetermined speed. At this time, the positive electrode sheet 202 and the negative electrode sheet 206 are provided so that their edge portions are offset from one another. Therefore, in a cell formed on the shaft 110, only the edge portion of the positive electrode sheet 202 protrudes in one direction of the shaft
25 and only the edge portion of the negative electrode sheet 206 protrudes in the other direction of the shaft.

[0069] In step S716, the winding apparatus 400 executes a winding-end process. This winding-end process is executed when a predetermined number of windings have been completed. This process includes a process in which the sheets are cut with the
30 sheet cutters 608 (FIG. 6) and a process in which the sheets are held in a predetermined state by the sheets holders 412 in preparation for the next winding process.

[0070] In step S718, the system controller 300 increases the counter p by 1, thus recording the completion of one winding process with respect to the shaft 110.

[0071] In step S720, the system controller 300 determines whether the counter p

is equal to 1. If the determination indicates that the counter p is 1 (i.e., YES in step S720), the routine proceeds on to step S722. If the determination does not indicate that the counter p is 1 (i.e., NO in step S720), the routine proceeds on to step S724.

5 **[0072]** In step S722, the system controller 300 moves the transfer apparatus 306 a predetermined interval with the linear guide controller 302. This predetermined interval is the width of the positive electrode sheet 202 or the negative electrode sheet 206. Moving the transfer apparatus 306 in this way enables the shaft 110 to be put in position for the next winding. The routine then returns to step S710.

10 **[0073]** In step S724, the insulation sheet winding apparatus 600 winds the insulation sheet onto the shaft 110. This winding process is executed after the positive electrode sheet 202, the negative electrode sheet 206, and the separator sheets 204 and 208 have finished being wound.

15 **[0074]** In step S726, the inserting machine 334 inserts the shaft 110, around which the insulation sheet has been wound, into the battery case 120. This is done after it has been confirmed that the insulation sheet is wound around the shaft 110 so as to prevent a shaft without the insulation sheet from being inserted into the battery case 120.

20 **[0075]** In step S728, the electrolytic solution injecting machine 360 injects a predetermined amount of electrolytic solution into the battery case 120 through the nozzle 362 according to a command from the system controller 300. The battery case 120 is then transferred to the crimping machine 350.

25 **[0076]** In step S730, the crimping machine 350 crimps the battery case 120 in a predetermined location on the outside according to a command from the system controller 300. This predetermined location is preset based on the size (length in the axial direction) of the cell in the secondary battery. The battery case 120 is then transferred to the sealing machine 370.

[0077] In step S732, the sealing machine 370 seals an open portion of the battery case 120 according to a command from the system controller 300 so as to prevent the electrolytic solution that has been injected into the battery case 120 from leaking out.

30 **[0078]** The operation of the manufacturing system 1000 according to the exemplary embodiment of the invention will now be described based on the foregoing described construction and flowchart.

[0079] The control data of the system controller 300 is initialized (step S702) and the shaft 110 is supplied to a predetermined location by the shaft supply apparatus 312 (step S704). The chucks 308 then grab the shaft 110 according to a command from the

linear guide controller 302 and set the shaft 110 in an initial state (step S706). After confirming that the chucks 308 have grabbed the shaft 110, the transfer apparatus 306 then moves to the winding apparatus 400 (step S708).

5 [0080] Once the shaft 110 is arranged in a predetermined location, the adhesive is applied to the ends of the positive electrode sheet 202, the negative electrode sheet 206, and the separator sheets 204 and 208 (step S710). After the ends of the sheets are then adhered to the shaft 110 by the pressure roller 402 (step S712), the loader 304 rotates holding the shaft 110 with the chucks 308 and the sheets start to be wound with the edge portions of the positive electrode sheet 202 and the negative electrode sheet 206 offset
10 (step S714).

[0081] Once the sheets have been wound a predetermined number of times, they are then cut with the sheet cutters 408 and the winding process ends (step S716). The sheets are then held in a predetermined location by the sheet holders 412.

15 [0082] The control data of the system controller 300 is then increased by 1 (step S718). If it is confirmed at this time that the first winding process has just been completed (i.e., YES in step S720), the linear guide controller 302 moves the transfer apparatus 306 a predetermined interval (step S722) where the adhesive is applied to the sheets so that they are set in the initial state again (step S710). The sheets are then adhered to the shaft 110 (step S712) and the winding process is performed again (step S714
20 and 716).

[0083] If, on the other hand, when the counter of the system controller 300 is increased by 1 (step S718), it is determined that the second winding process has just been completed (i.e., NO in step S720), the linear guide controller 302 moves the transfer apparatus 306 to a predetermined location with respect to the insulation sheet winding
25 apparatus 600. After the insulation sheet 210 has been wound on the sheet 110 (step S724), the transfer apparatus 306 moves to a predetermined location and rotates so that it is facing the opposite direction that it was previously facing. The chucks 308 then release the shaft 110 in a predetermined location for the inserting machine 334.

30 [0084] After the inserting machine 334 inserts the shaft 110 into the battery case 120 (step S726), the battery case 120 is then rotated so that an open portion thereof faces upward. The electrolytic solution injecting machine 360 then injects electrolytic solution into the open portion (step S728) and the battery case 120 is then transferred to the crimping machine 350. The crimping machine 350 then crimps the battery case 120 at a predetermined location, thus joining the cells at the connecting portion (step S730). After

this is done, the battery case 120 is transferred on a belt conveyer 340 to a predetermined location with respect to the sealing machine 370. The sealing machine 370 then seals the open portion of the battery case 120 (step S732), after which the battery case 120 is transferred on to the next process.

5 **[0085]** According to the secondary battery 100, the manufacturing system 1000, and the manufacturing method according to the first exemplary embodiment of the invention as described above, the positive electrode sheet 202 and the negative electrode sheet 206 are wound, with the separator sheets 204 and 208 alternately interspersed in between, around the shaft 110 of the secondary battery in such a way that the edge portion
10 of the positive electrode sheet 202 is offset from the edge portion of the negative electrode sheet 206 in the direction in which the cells connect. Accordingly, the edge portion of the positive electrode sheet 202 and the edge portion of the negative electrode sheet 206 can be used to connect adjacent cells, which obviates the need for a separate connecting member and process. As a result, internal resistance from the connection between the cells is
15 reduced so output of the secondary battery can be improved. Therefore, it is possible to provide a secondary battery, a manufacturing system, and manufacturing method for that secondary battery that can improve output and reduce the number of parts and manufacturing processes.

[0086] In the manufacturing system and manufacturing method for the
20 secondary battery according to this exemplary embodiment of the invention, a first forming step (step S714) is performed by the winding apparatus 400 to form a cell in which the edge portion of the positive electrode sheet 202 and the edge portion of the negative electrode sheet 206 are offset in the direction in which the cells are connected. Further, a second forming step (step S714 which is executed again after step S722) is also performed
25 in the same way by the winding apparatus 400 to form another cell in which the edge portion of an electrode having a different polarity from the electrode of the cell formed in the first forming step overlaps with the edge portion of the electrode of the cell formed in the first forming step.

[0087] That is, after the winding of the sheets in the first forming step (step
30 S714) is complete, the transfer apparatus holding the shaft 110 is moved (step S722) and the winding of sheets in the second forming step is performed (step S714). Alternatively, however, the second forming step may be performed without changing the position of the shaft 110. In this case, the second forming step (step S714 after step S722 is performed) can be performed by providing another winding apparatus having the same function as the

winding apparatus 400 next to the location where the sheets are wound by the winding apparatus 400. This eliminates the time it takes to move the shaft 110, thereby improving efficiency in the winding process.

[0088] [Second Exemplary Embodiment]

5 A second exemplary embodiment of the invention will hereinafter be described with reference to FIGS. 8 to 10B.

[0089] The construction of a secondary battery 800 according to the second exemplary embodiment of the invention will now be described referring to FIG. 8. As shown in the drawing, the secondary battery 800 according to this modified example
10 includes the shaft 110, positive and negative electrode sheets and separator sheets wound around the shaft 110, an insulation sheet (not shown), a battery case 820, rings 830 fit around the battery case 820 at predetermined intervals, and electrolytic solution (not shown) filled inside the battery case 820.

[0090] The positive and negative electrode sheets, separator sheets, and
15 insulation sheet are wound around the shaft 110 in the same manner as in the secondary battery 100 according to the first exemplary embodiment so descriptions thereof will not be repeated.

[0091] A manufacturing system 2000 for manufacturing the secondary battery 800 according to the second exemplary embodiment of the invention will now be described
20 with reference to FIG. 9. This manufacturing system 2000 differs from the manufacturing system 1000 according to the first exemplary embodiment in that it includes a ring supplying machine 950 and a ring press machine 952 instead of the crimping machine 350 (FIG. 3). The other manufacturing equipment is the same as that used in the manufacturing system 1000 so descriptions thereof will be omitted.

25 **[0092]** The ring supplying machine 950 supplies the rings 830 to predetermined locations on the secondary battery 800 (FIG. 8). The ring press machine 952 then presses the rings 830 from the outside toward the secondary battery 800 so as to join adjacent cells at the connecting portion.

[0093] Accordingly, by fitting the rings 830 at the joining portion of the cells, it
30 is possible to reinforce the joined state of the connecting portion of the cells. Further, even in cases where joining by crimping (at the crimping portion 130 in FIG. 1) is not possible, the pressed rings enable internal resistance to be reduced, thereby suppressing a reduction in output voltage.

[0094] The manufacturing method of the secondary battery 800 according to this

exemplary embodiment of the invention will now be described with reference to the flowchart of FIGS. 10A and 10B. This manufacturing method may be used with the manufacturing system 2000 shown in FIG. 9, for example.

[0095] The method for manufacturing the secondary battery according to this exemplary embodiment differs from the method for manufacturing the secondary battery according to the first exemplary embodiment (FIGS. 7A and 7B) in that after injection of electrolytic solution (step S728), a process is performed to join adjacent cells at the connecting portion using rings (step S1030). The other processes are the same as the those in the manufacturing method according to the first exemplary embodiment so descriptions thereof will be omitted.

[0096] In step S1030, the ring press machine 952 presses the rings 830 supplied to a predetermined location by the ring supply machine 950. This predetermined location is the connecting portion between adjacent cells in the secondary battery 800. The rings 830 are then pressed, for example, in a direction from a closed portion (not shown) of the secondary battery 800 toward an open portion (also not shown) of the secondary battery 800 at each connecting portion so as to release the stress in a secondary battery case 820 from the open portion.

[0097] The operation of the manufacturing system 2000 according to the exemplary embodiment of the invention will now be described based on the construction and flowchart described above. Descriptions of the operations that are the same as those of the manufacturing system 1000 according to the first exemplary embodiment will be omitted.

[0098] After the electrolytic solution injecting machine 360 injects the electrolytic solution into the open portion of the secondary battery 800 (step S728), the belt conveyer 340 transfers the secondary battery 800 with the injected electrolytic solution to the ring press machine 952. One of the rings 830 is then supplied to the secondary battery 800 by the ring supply machine 950, and the ring press machine 952 presses the ring 830 onto the secondary battery 800 at a predetermined location so as to join the cells at the connecting portion (step S1030). The open portion of the battery case 820 is then sealed and the secondary battery 800 is transferred to the next process.

[0099] According to the secondary battery 800, the manufacturing system 2000, and the manufacturing method according to the second exemplary embodiment of the invention, a plurality of cells in the secondary battery 800 are joined at connecting portions by pressing the rings 830 provided around the outside of the cells. In this case, the rings

830 deform from the pressure so even after the pressure is released from the rings 830, adjacent cells are maintained in a joined state at the connecting portions. Accordingly, even in a case where the material of the battery case 120 is not suitable for plastic deformation (such as a resin film), adjacent cells can be reliably connected so internal resistance in the secondary battery 800 can be reduced.

[0100] [Third Exemplary Embodiment]

A third exemplary embodiment of the invention will hereinafter be described with reference to FIGS. 11 to 13B.

[0101] The construction of a secondary battery 1100 according to this exemplary embodiment will now be described referring to FIG. 11. As shown in the drawing, the secondary battery 1100 according to this exemplary embodiment includes the shaft 110, positive and negative electrode sheets and separator sheets, and an insulation sheet (not shown), all of which are wound around the shaft 110, a battery case 1120, and electrolytic solution (not shown) filled inside the battery case 1120. The secondary battery 1100 is welded at weld zones 1130 spaced at predetermined intervals.

[0102] The positive and negative electrode sheets, separator sheets, and insulation sheet are wound around the shaft 110 in the same manner as with the secondary battery 100 according to the first exemplary embodiment so descriptions thereof will not be repeated.

[0103] A manufacturing system 3000 for manufacturing the secondary battery 1100 according to the third exemplary embodiment of the invention will now be described with reference to FIG. 12. This manufacturing system 3000 differs from the manufacturing system 1000 according to the first exemplary embodiment in that it includes two welding machines 1250 instead of the crimping machine 350 (FIG. 3). The other manufacturing equipment is the same as that used in the manufacturing system 1000 so descriptions thereof will be omitted.

[0104] The welding machine 1250 welds the secondary battery 1100 in predetermined locations. Any of various welding methods may be used, including, but not limited to, ultrasonic welding and laser welding.

[0105] Accordingly, by welding the connecting portion of the cells, it is possible to reinforce the joined state of the electrodes at the connecting portion. Further, even in cases where joining by crimping (at the crimping portion 130 in FIG. 1) is not possible, welding enables internal resistance to be reduced, thereby suppressing a reduction in output voltage.

[0106] The manufacturing method of the secondary battery 1100 according to this exemplary embodiment of the invention will now be described with reference to the flowchart of FIGS. 13A and 13B. This manufacturing method may be used with the manufacturing system 3000 shown in FIG. 12, for example.

5 **[0107]** The method for manufacturing the secondary battery according to this exemplary embodiment differs from the method for manufacturing the secondary battery according to the first exemplary embodiment (FIGS. 7A and 7B) in that after the injection of electrolytic solution (step S728), a process is performed to join adjacent cells at the connecting portion by welding (step S1330). The other processes are the same as the
10 those in the manufacturing method according to the first exemplary embodiment so descriptions thereof will be omitted.

[0108] In step S1330, the welding machine 1250 welds the secondary battery 1100 in a predetermined location. This predetermined location is a portion where adjacent cells in the secondary battery 1100 are to be connected.

15 **[0109]** The operation of the manufacturing system 3000 according to the exemplary embodiment of the invention will now be described based on the construction and flowchart described above. Description of the operations that are the same as those of the manufacturing system 1000 according to the first exemplary embodiment will be omitted.

20 **[0110]** After the electrolytic solution injecting machine 360 injects the electrolytic solution into the open portion of the secondary battery 1100 (S728), the belt conveyer 340 transfers the secondary battery 1100 with the injected electrolytic solution to the welding machine 1250. The welding machine 1250 then welds the secondary battery 1100 at predetermined locations (step S1330), thus joining the cells at the connecting
25 portions.

[0111] According to the secondary battery 1100, the manufacturing system 3000, and the manufacturing method according to the third exemplary embodiment of the invention, the portions where adjacent cells in the secondary battery 1100 are to be connected are joined by welding, thus enabling a reliable connection. Accordingly,
30 internal resistance is reduced so output from the secondary battery 1100 can be improved. Also, because there is no need for a connecting member, the process of attaching such a connecting member is also unnecessary. As a result, it is possible to provide a secondary battery, a manufacturing system, and manufacturing method for that secondary battery which can improve output and reduce the number of parts and manufacturing processes.

[0112] In the illustrated embodiment, the controllers are implemented with general purpose processors. It will be appreciated by those skilled in the art that the controllers can be implemented using a single special purpose integrated circuit (e.g., ASIC) having a main or central processor section for overall, system-level control, and separate sections dedicated to performing various different specific computations, functions and other processes under control of the central processor section. The controllers can be a plurality of separate dedicated or programmable integrated or other electronic circuits or devices (e.g., hardwired electronic or logic circuits such as discrete element circuits, or programmable logic devices such as PLDs, PLAs, PALs or the like). The controllers can be suitably programmed for use with a general purpose computer, e.g., a microprocessor, microcontroller or other processor device (CPU or MPU), either alone or in conjunction with one or more peripheral (e.g., integrated circuit) data and signal processing devices. In general, any device or assembly of devices on which a finite state machine capable of implementing the procedures described herein can be used as the controllers. A distributed processing architecture can be used for maximum data/signal processing capability and speed.

[0113] While the invention has been described with reference to preferred embodiments thereof, it is to be understood that the invention is not limited to the preferred embodiments or constructions. To the contrary, the invention is intended to cover various modifications and equivalent arrangements. In addition, while the various elements of the preferred embodiments are shown in various combinations and configurations, which are exemplary, other combinations and configurations, including more, less or only a single element, are also within the spirit and scope of the invention.